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A SAND FEEDER FOR USE IN LABORATORY LITTORAL TRANSPORT STUDIES

by

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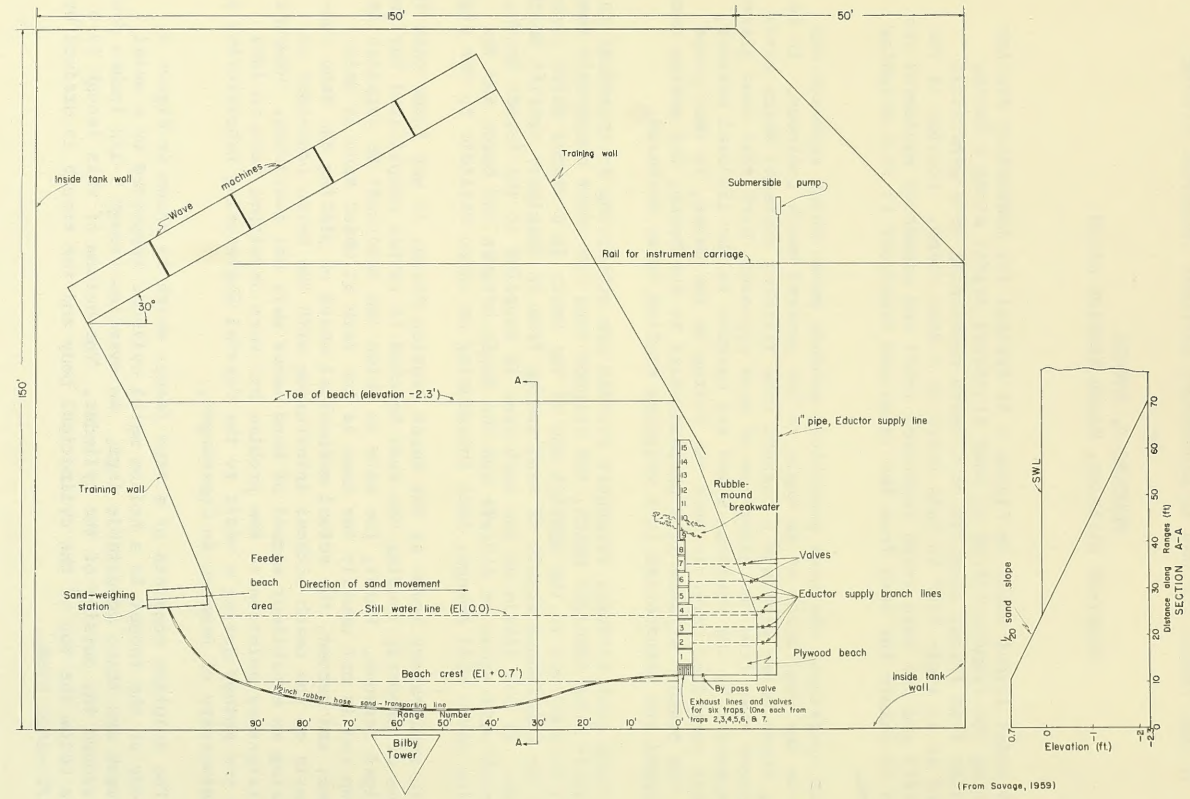
A model layout shown in Figure 1 is typical for laboratory studies involving the transportation of sand (littoral drift) along a beach. Basically this layout consists of a basin containing wave generators aligned at an angle (30° in this case) to a sand beach. Located at the downdrift end are sand traps (numbered 1-15) and accessory equipment required to remove the sand from the traps and transport it to a weighing station.

In operation, the wave generators produce waves which approach and break on the sand beach at an angle to the general beach contours. In so doing, these waves generate a current (the littoral current) which moves alongshore away from the direction of wave approach. Both that sand placed in suspension by the breaking waves and carried in the littoral current, and that propelled directly over the bottom by the waves, is then moved along the beach. At some line perpendicular to the beach, the moving sand is trapped and transferred to a weighing station to be measured.

Since most littoral transport studies are attempting to represent an infinitely long straight beach, the trapped sand (or other comparable sand) should be supplied to the updrift end of the beach in a manner which simulates the continuous supply of sand coming from an imaginary updrift beach section. If too little or too much sand is supplied to the feeder beach, the beach will erode or accrete and the angle between the beach and the incoming waves will change, thus introducing an added variable to the study.

In exploratory tests at the Beach Erosion Board, it was found that the problem of properly feeding the test beaches is rather complicated for two principal reasons. First, the rate at which the sand must be supplied is unknown and is not usually the same as the rate at which sand is being trapped; and second, the actual mechanical means of placing the sand continuously on the beach without interfering with the beach processes or utilizing an exorbitant amount of hand labor were not available. However, a satisfactory solution to the problem has been developed from an idea given the author during a visit to the Coastal Engineering Laboratories of the University of Denmark in Copenhagen.

The solution consists of a sand feeder which is shown in Figure 2. The body of the feeder is a hollow metal cylinder supported by a metal framework and three adjustable legs. An overflow trough 5-1/2 inches deep fits around the outside of the cylinder. The bottom of this trough is 6 inches below the top of the cylindrical body and the trough is drained by a 2-1/2 -inch hose.



(From Savage, 1959)

FIGURE 1 LAYOUT OF GROIN STUDY IN THE SHORE PROCESSES TEST BASIN.

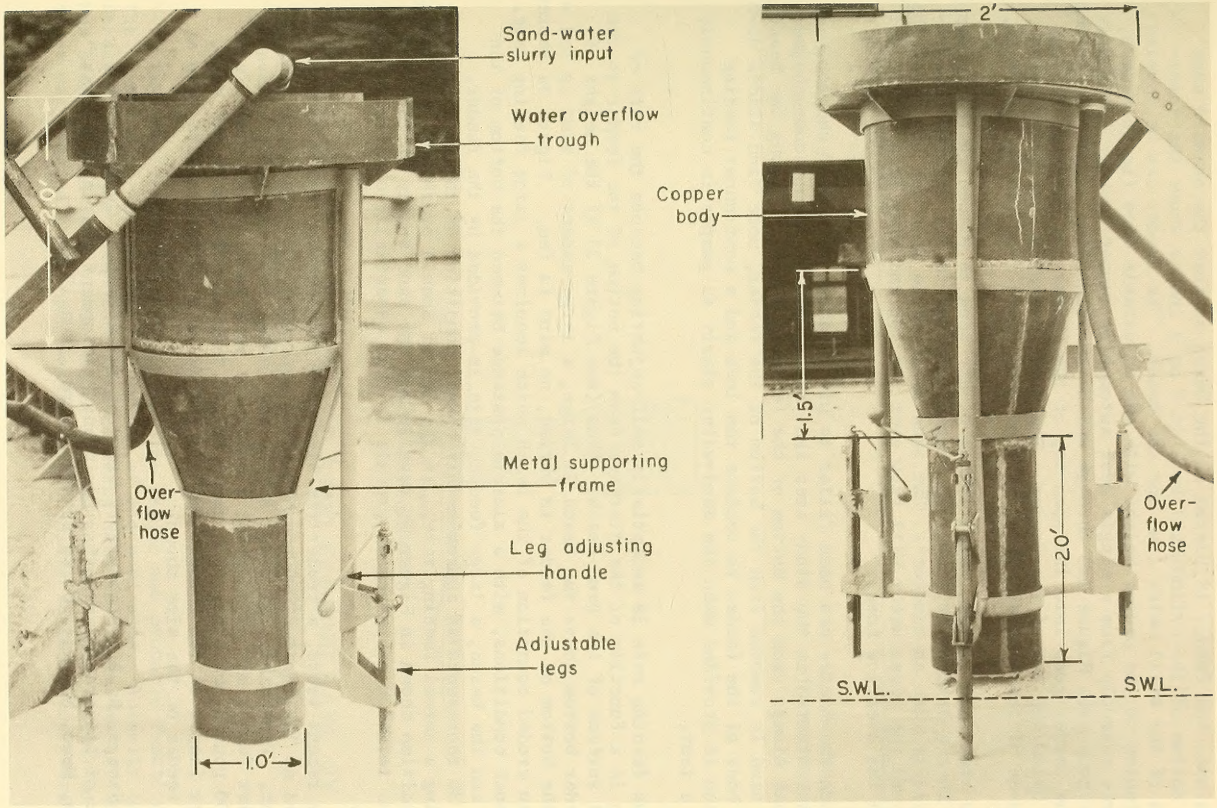


Figure 2. A SAND FEEDER FOR USE IN LABORATORY LITTORAL TRANSPORT STUDIES

In use, the feeder is placed on the beach so that the seaward edge of the bottom of the cylindrical body is 1 or 2 inches above the intersection of the still water line and the beach. The feeder can be leveled and adjusted to the proper height with the adjustable legs (in this case, the screw assembly from a single post automobile bumper Jack). The supply pipe or hose (see Figure 2a) through which the sand-water slurry is carried into the feeder goes into the open top of the feeder and discharges about 1 foot below the top of the feeder. The water overflow hose is arranged to dispose of the overflow water at some point away from the feeder beach.

To start the feeder, about 1 foot of dry sand is placed in the feeder body. Then a sand-water slurry is pumped into the feeder from the measuring facility with an eductor*. The sand will settle into the bottom of the feeder and the clear water will flow over the top and away from the feeder through the overflow hose.

When the feeder has been filled to within about a foot of the top, waves are started in the study area and they take sand from a cone-shaped pile that slumps from the bottom of the feeder and move it along the beach. As the sand is removed from the bottom of the feeder, more sand slides down to the body of the feeder to replace the loss and a continuous feeding operation is provided when the sand-water slurry is pumped in continuously during a test.

The feeding rate is essentially self-adjusting because the rate of feeding is a function of the distance from the bottom of the feeder to the general surface of the sand beach. Thus (see Figure 3) if the height of the feeder bottom above the beach is large, a large amount of sand is fed - or if the bottom of the feeder is buried, no sand is fed. Figure 3a represents an eroded condition of the beach which requires a large feeding rate. Under such conditions, with a sizable distance between the bottom of the feeder and the beach, a large feeding rate is provided by the feeder. Figure 3b represents an approximately normal condition of the beach profile requiring a normal feeding rate. If the feeder should oversupply the beach, the condition shown in Figure 3c results and the sand supply is cut off. Thus the location of the beach profile is held essentially constant by the feeder.

In recent tests, a feeder the size of the one shown in Figure 2 has supplied as little as 2,000 pounds and as much as 15,000 pounds of sand per hour. Presumably, it could supply any lesser rate required; however, a smaller feeder may give better results for very small rates - say less than 100 pounds per hour. For rates larger than 15,000 pounds per hour, a larger feeder or two feeders would probably give better results than a single feeder of the size shown.

* See Savage, R. P. "Laboratory Study of the Effect of Groins on the Rate of Littoral Transport: Equipment Development and Initial Tests", Tech. Memo. No. 114, Beach Erosion Board, June 1959.

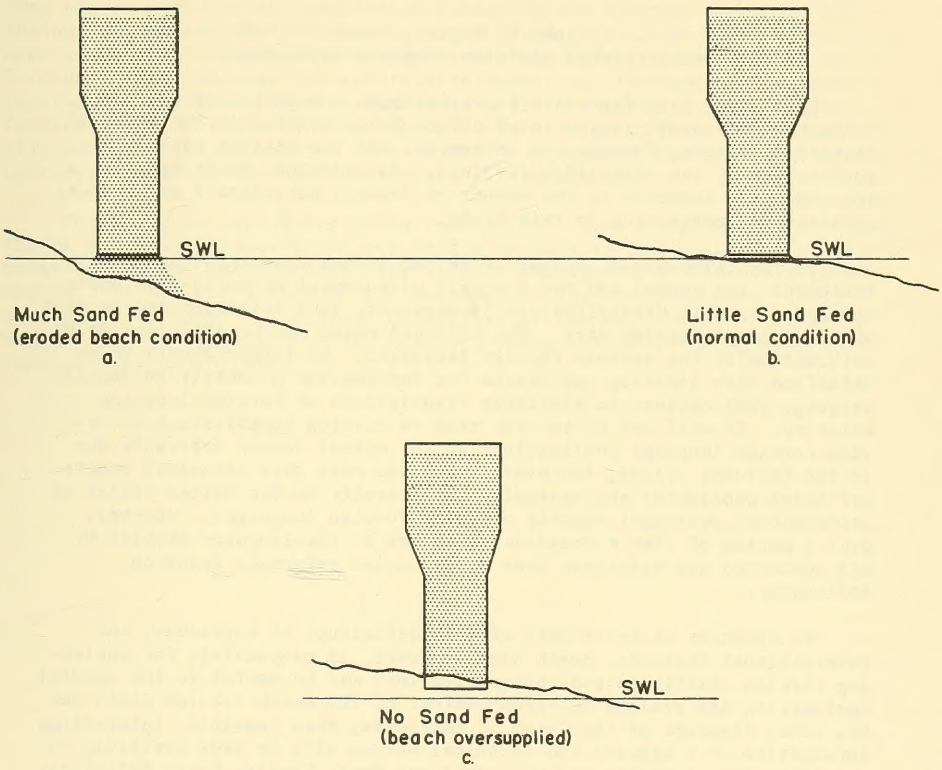


FIGURE 3. CONTROL OF SAND FEEDING RATE BY THE BEACH PROFILE ADJUSTMENT.

The best location and height of the feeder are probably functions of the feeder size and the particle sizes of the sand used. Actually only a feeder of the size shown in Figure 2, using sand of 0.2-mm. median diameter, has been used in tests at the Beach Erosion Board. Other feeder and sand sizes may require some experimentation to achieve satisfactory results.

FOREIGN COASTAL ENGINEERING AND RELATED RESEARCH*

by

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During the past few years there has been a significant increase throughout the world in the total effort being devoted to the study of coastal processes, forces, and phenomena, and the related engineering application of the scientific findings. In addition, there has been a corresponding increase in the number of foreign periodicals and special publications pertaining to this field.

In the interest of economy of United States resources (manpower, equipment, and money) and the over-all advancement of world-wide basic knowledge in this discipline, it is necessary that increased use be made of all related foreign data. The critical phase is the exploitation of information in the various foreign languages. No longer should we be satisfied with limiting our search for information primarily to English language publications or available translations of foreign language articles. It will not be an easy task to develop capabilities to review foreign language publications to the extent deemed desirable due to two factors: first, the ever increasing rate that technical papers are being published; and secondly, the scarcity in the United States of professional personnel capable of using foreign languages. However, over a period of time a coordinated attack on the language problem by all concerned may eliminate most of the noted reference research deficiency.

To overcome at least part of this deficiency of knowledge, the International Division, Beach Erosion Board, is responsible for analyzing foreign activities and information that may be useful to the coastal engineering and related research* effort of the Beach Erosion Board and the other elements of the Corps of Engineers. When possible, interesting information of a general and technical nature will be made available to all interested agencies and personnel via Beach Erosion Board Bulletins, Technical Memoranda, or such other media as may be deemed appropriate. The first such release is a general information article in this Bulletin entitled "Soviet Scientific Progress in Coastal Oceanography". Description of a new Soviet manual on coastal engineering is also included in this Bulletin as a separate release.

It is hoped that the Beach Erosion Board will develop as a primary focal point in the U. S. Government for foreign information in the field of coastal engineering and related research. To further this objective

* Coastal engineering and related research includes: the collection of basic information on coastal environment, processes, forces, and phenomena; the performance of basic and applied research in this field; and the development of engineering data and design criteria for protecting the coastal environment against coastal processes and forces.

it would be appreciated if U. S. authors would furnish the Beach Erosion Board pertinent bibligraphical data of their periodical articles or special reports pertaining to foreign coastal research and engineering. Even better would be the receipt of a copy of the article or report for inclusion in that Board's Library. At a later date it is proposed to make a survey of holdings of United States agencies for information on foreign coastal engineering and related research. Foreign publications received at the Beach Erosion Board, as well as special reports by the International Division or other agencies on foreign activities, accomplishments, or environments, will be made a permanent part of the Board's Library, available for use by research personnel.

The Beach Erosion Board looks forward to a more complete understanding of the accomplishments of our fellow scientists and engineers in all countries of the world, especially in the investigation of coastal processes, forces, and phenomena and the engineering application of their findings. Although the current capability of the Beach Erosion Board to handle foreign language data is limited, every effort is being made to improve that capability.

SOVIET SCIENTIFIC PROGRESS IN COASTAL OCEANOGRAPHY

by

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SOVIET EFFORT FOR INTERNATIONAL COOPERATION IN COASTAL INVESTIGATIONS

At the Twelfth Assembly of the International Union of Geodesy and Geophysics (IUGG), held in Helsinki, Finland, in August 1960, the Soviets proposed the establishment of a special committee within the framework of the International Association of Physical Oceanography (IAPO), a subdivision of IUGG, for the study of dynamics of shores and coastal zones. The leading Soviet oceanographers V. P. Zenkovich and V. N. Longinov, authors of the proposal, consider the present methods and means of oceanographic studies of coastal processes, now carried on separately by individual countries, inadequate for the advancement of knowledge of phenomena occurring in the shore zone. They consider the general processes occurring in any shore zone to be subordinated to the same laws of geophysics, which cannot be scientifically investigated without international coordination and mutual use of achievement of different countries.

The Soviet proposal for the establishment of a special committee of IAPO, outlined the following objectives:

1) collection and distribution of information on investigations and methods used in various countries;

2) preparation of a program for a symposium to be held at the next IUGG meeting;

3) preparation of a program of studies in nature and model laboratories within the symposium mentioned under 2);

4) standardization of international terminology for coastal zone studies;

5) coordination of studies carried out in different countries, exchange of information, also arrangement for consultation of competent specialists;

6) publication of material of the Committee in a special bulletin; and

7) organization of a symposion for IUGG Assembly in 1967-68, in which the results should be discussed and future programs elaborated.

The Soviet proposal is supplemented by a list of specific coastal problems considered as the most important part of the program of shore

dynamics and shore zone investigations and which should be subjected to international cooperation. These problems are:

a) transformation of wave movements in shallow zones and study of wave velocities and their assymetry,

b) currents generated by waves and other currents in the shore zone,

c) mechanism of moving and shifting of debris of different sizes,

d) establishment of bottom equilibrium profile,

e) study of migration of debris along the shore and of physical parameters of debris streams,

f) formation of embankments and straightening of shores,

g) laws of the shore zone development as a part of general geophysical picture of lithosphere evolution, and

h) physical processes in the shore zone as part of the total energy balance of the earth's surface.

The acceptance of the Soviet proposal in Helsinki by IAPO, and appointment of V. P. Zenkovich to chairmanship of the Committee for the study of dynamics of shores and coastal zone, indicates a certain international recognition of recent achievements of Soviet coastal scientists and oceanographers.

It is not as yet clear whether the Committee will be successful in promoting the proposed international cooperation.

ORGANIZATION AND EXECUTION OF COASTAL RESEARCH IN U.S.S.R.

Soviet entry into scientific investigations of shores and coastal zones of oceans, seas, and lakes is of relatively recent origin. For example, the publication of the works by V. P. Zenkovich in 1946 (90-92), are comparable to that of the United States of 1919 - when the book by D. W. Johnson: "Shore Processes and Shoreline Development" (13), was published.

The effort of Soviet scientists, oceanographers, and engineers specializing in coastal research since World War II, however, deserves special attention. A group of individuals associated with Zenkovich, among them, in particular N. N. Dzhunkovskiy (1,2), Y. G. Kachugin(15,16), N. Y. Kondrat'yev (21-27), O. K. Leont'yev (33-40) , V. V. Longinov (44-59), B. A. Pushkin (61-71), G. S. Solotaryev (77,78), and others, was able to produce voluminous scientific and technical literature on the subject.

The German oceanographer, Griesseier [12] lists two hundred bibliographic items (books, articles, papers, and others) published in U.S.S.R. between 1946 and 1958, dealing with coastal phenomena and their scientific investigations. The lack of knowledge of the Russian language, together with difficulties encountered in obtaining the publications, accounts for a very limited knowledge in the West of this Soviet progress.

In 1952, upon initiative of the Academy of Sciences, U.S.S.R. and the leadership of V. P. Zenkovich [90-116], the Soviets established at the Presidium of Soviet Academy of Sciences, U.S.S.R. a central organization with an overall planning and coordinating authority in the field of coastal research under the name, The Shore Section of the Oceanographic Commission. The execution of the scientific coastal research is entrusted to a great variety of institutions throughout the U.S.S.R. which are divided into four groups. The largest group is made up of institutions under the guidance of The Academy of Sciences, U.S.S.R., such as Institute of Oceanology, Institute of Marine Hydrophysics, and others. The second largest group is composed of government institutions, subordinated to the State Ministries or All-Union central governmental agencies such as Central Scientific Research Institute of the Maritime Fleet, subordinated to the Ministry of the Maritime Fleet; State Oceanographic Institute, subordinated to the Chief Directorate of the Hydrometeorological Service. The third group comprises institutions of higher learning, universities, colleges, graduate schools with advanced curricula in geophysics, geography, and hydrodynamics, such as M. V. Lomonozov Moscow State University. The fourth group includes regional institutions, associated with individual Soviet Republics such as Institute of Hydrology and Hydrotechnics of the Academy of Sciences, Ukranian S. S. R. A great number of the institutions mentioned have experimental laboratories associated with them. The majority of them publish regularly a record of their studies and investigations in the form of transactions (Trudy), bulletin (Izvestiya), paper (Doklady); books and periodicals. Outstanding among these are bulletin (Izvestiya) of the Academy of Sciences, U.S.S.R., the Geophysics and Geographic Series, "Trudy" of Oceanologic Institute, "Trudy" of Sea Hydrophysical Institute, or "Trudy" of Geographic Institute, U.S.S.R., "Okeanologia", and many others. They indicate the existence of a broad movement for organization of coastal research, equipped with facilities, served by an extensive staff of professionals.

SOVIET COASTAL INVESTIGATIONS

The problems involved in the Soviet coastal investigations reflect the influence of Russia's basic geography, namely her limited access to the ice-free oceans through Black and Baltic Seas toward the Atlantic, her long shore lines on the Arctic and North Pacific Oceans which are influenced by perma-frost conditions and the closed-in Caspian and Aral Seas with limited tidal conditions, all of which have no analogy elsewhere in the world. In addition, the large inland reservoirs sometimes called "seas", constructed in the last 40 years in connection with the hydrotechnical program of the U.S.S.R. present a coastal problem of specific nature, due to their areal extent.

The Soviet Theory of Dynamics and Morphology of the Shores of Seas and Lakes - As developed by V. P. Zenkovich and the school of oceanographers associated with him, the theory considers the coastal zone, below and above the sea level, as a genetic unit and the changes of the relief and structure of the shores as a result of energy moving from the center of the sea basin to its periphery. The principal energetic elements - the waves and currents after reaching the coastal region, generate the motion of materials on the sea bottom and the processes observed in the shore zone. According to Zenkovich, the knowledge of hydrodynamics of the shore zone is very unsatisfactory, despite the experience in predicting the parameters of sea waves, their refraction and diffraction. Their internal structure and the mechanism of their action on the sea bottom is, however, very little known; also the overall hydrodynamics of the coastal zone are not convincingly explored up to the present. Phenomena, such as breaking processes and material-moving action of the waves, assymetry of the wave elements in the proximity of the shore and floor leveling current which brakes the landward movement while accelerating the seaward movement of the water, belong in the category of unexplored processes. In addition, the theory of transition from hydrodynamics to the dynamics of material movement in general use is deficient due to difficulties experienced in laboratory model representation being so far developed without substantiation by observations and measurements under natural conditions. Extreme efforts are underway in U.S.S.R. to perfect and amplify the theory of Zenkovich on the formation of accumulative form of the shore and dynamic classification of these forms (53).

Behind the efforts for theoretical solution of coastal problems, the main obvious purpose is to obtain a working basis for planning and maintenance of maritime improvements. Numerous papers and studies with particular regard for measurements and observations, taken under natural conditions have been published (45,49,58,59,96,3-11).

Surveys and Studies of Soviet Seashores - The Soviets have made numerous surveys of their coastal areas, many of them of regional character, and studied in detail the related physical characteristics and natural phenomena. These studies are on energy transformation by the movement of water masses, deformation of waves, transport of material, changes of the physical relief in the coastal zone resulting from erosion or accretion (17,18,32-34, 37, 39, 64, 89, 115). These studies contain comprehensive and detailed information on the dynamics and morphology of shores of different seas of U.S.S.R. Data from the surveys and studies are compiled in regional monographs used in preparation of Survey of Seashores of U.S.S.R. (Kadastr Beregov Morei S.S.S.R.),(36,105). The data are organized as follows:

a) brief introduction to the theory of dynamics and morphology of seashores with attention given to the local peculiarities;

b) general characteristics of the basin, its shores and the adjoining mainland - hydrometeorology, geology and geomorphology;

c) exploitation of the sea basin and its shore in the past, review of historical monuments, documents, maps, and other material;

d) division of the shore into typical sectors and descriptions of them according to b);

e) analysis of the dynamics and regime of these individual sectors with a prognosis of their further development and estimation for their exploitation; and

f) summary, conclusions, and maps.

The establishment of the survey of seashores is considered of great economic importance for the rational planning and developing of maritime construction for coastal protection, harbors, and landing facilities and coastal engineering in general.

Artificial Seas of U.S.S.R. - The construction of immense retention reservoirs with dimensions comparable to those of largest natural inland lakes, underway for the past 40 years within the hydrotechnical program of Russia's water resources, was initiated by the Great Volga Waterway [14], in 1926. As an example, Kuybyshev "Sea", an artificial storage reservoir created by a multiple-purpose dam, raises the Volga stage by 24 m. at Kuybyshev and extends for a distance of 500 km. (310 miles). It averages 40 to 60 km. (25 to 37 miles) in width and retains 38 cu. km. (31 million acre-feet) of water. These artificial reservoir creations are subject to coastal processes of their own and obey certain laws typical of them. An important consideration in these reservoirs is the role played by wind waves up to 3.5 m (12 feet) high, and their action on the shores. These phenomena have become the subject of studies and investigations of experts in a variety of sciences [14-16, 18-22, 28, 29, 31, 41-43, 60-63, 68,69, 72,73, 75-79, 83-85]. The changes in the shoreline of these reservoirs, in the course of filling up, inhibit the planning and construction of industrial plants, agricultural installations, and human settlements, as well as of piers, harbors, railroad lines, and highways along the shore. The key to these problems is to originate reliable methods for predicting the changes in the shores during the filling-up process of the reservoir. The experience and theory on the dynamics and morphology of seashores is of very little use, because these changes include both the process of formation of the shore slope during the reservoir filling and those during the operation of the waterway and hydropower plant at various stages of flood. The concept of uniformity in the process of formation of shore slope above and under the water is the basis for the methods presently used for the reservoir construction. The shore slope is considered a surface on which the destruction of the energy of waves attacking the shores takes place.

Silting Processes in Harbors and Navigation Canals - Study of silting is a very important part of Soviet coastal research with particular regard for disintegration of shores along detrital and sandy coasts. Numerous investigations are carried on, to establish reciprocal relations between a variety of structures connected with maritime constructions, such as breakwaters, moles, shore revetments, groins, and others [16,69]. The

protective measures taken along detrital coasts of the Black Sea and sandy shores of the Baltic Sea have been treated on the basis of the laws of dynamics and morphology of shores (19,20,30).

Soviet Coastal Investigations of Sea Outlets of Large Rivers (Deltas) - Considerable attention in U.S.S.R. is given to phenomena involved in coastal areas penetrated by outlets of large rivers (deltas). Usually where suitable for the construction of large harbors, a systematic observation is carried out in these areas in connection with the inland waterways construction program and for the purpose of maritime and coastal engineering. Voluminous scientific material on problems of dynamics and morphology of large river deltas was evaluated and published. I. V. Samoilov, in his book "River Outlets" (74), presents a survey and analysis of these problems, including the description of deltas of major Russian rivers. The book also covers deltas of major large rivers of the world.

Methods and Techniques of Soviet Coastal Research - The research methods are not as yet developed as to indicate a definite standard, although an attempt in this direction is noticeable. Most of the methods are described in special studies, which deal with specific problems of dynamics and morphology of shores including lithological and mineralogical analysis of the material (40,99,102,115), quantitative analysis (3,19,20,25,28,30,33,44,58), and laboratory model presentation (30). Several of these methods have been merged and supplemented in some cases with diver observations (81,82). Electric and photographic methods are, however, gaining importance (42,48, 55-57, 76,87). Particularly well developed are methods of indicators, marked debris, colored or activated sand (65-66).

CONCLUSIONS

The establishment of a central scientific authority in charge of investigations of shore zone processes organized as The Shore Section of the Oceanographic Commission under the Presidium of the Academy of Sciences, U.S.S.R. indicates the Soviet Government's interest in coastal problems of engineering and construction. Emphasis is placed on economic and strategic planning.

This central authority coordinates and directs the activities of a large number of research institutions and agencies in all parts of U.S.S.R. These institutions are abundantly endowed with equipment, including laboratories and experimental and observation stations and are staffed with numerous scientific and engineering personnel. The voluminous literature listed in the bibliography, covering a great variety of subjects in the coastal field was produced during the period 1946 to 1958. Since 1958, the volume of publications in coastal research has increased at an accelerated rate.

The extent of Soviet scientific and technological activities in the field of physical oceanography and coastal phenomena is formidable in itself. The objective evaluation of these activities, by means of reviewing the voluminous and growing Russian professional literature, presents a most difficult task, complicated by highly theoretical treatment applied in research and studies, as well as by the terminology and language obstacles.

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NEW SOVIET MANUAL ON COASTAL ENGINEERING*

The Soviet delegation to the XXth International Navigation Congress, ...e, Maryland, presented to the Beach Erosion Board a copy of their ...anual on coastal engineering, i.e., "Technical Instructions for ...ning Effect of Waves on Maritime and River Constructions and ... - Construction Norm 92-60", dated 21 April 1961, issued by the ...Committee on Structural Works, USSR Council of Ministers, Moscow.

This manual which apparently supersedes the All-Union State Standard ...46 appears to be a partial equivalent of the Beach Erosion Board's ...ical Report No. 4, "Shore Protection Planning and Design". The Soviet ...l of 132 pages (5 x 8 inches), 86 graphs and drawings, and 17 tables ...ivided into 7 chapters and 4 supplements (annexes). It presents a ...t theoretical analysis of wave theory, practical application of con- ...tion norms to structures and shores, and examples of computation ...s. The titles of the seven chapters and four supplements (and ...of pages involved) are:

...ch... manu... is d... Shor...

...I General instructions and definitions. (5 pages)

Determination of the parameters of wind waves. (27 pages)

...I Determination of the effects of waves on types of structures with vertical (or nearly vertical) walls. (19 pages)

IV Determination of the effects of waves on sloping structures. (7 pages)

V Determination of the effects of waves on individual piles and open-work construction. (19 pages)

VI Determination of the effects of waves on shore protection construction. (8 pages)

VII Determination of the effects of wake waves on construction protecting canal banks. (3 pages)

Annex I - Table of approximate maximum fetches (in various areas and reservoirs). (1 short table)

*This is the first announcement (in recent years) on foreign coastal engineering publications considered of significant interest to the United States coastal engineering and related research effort. The International Division, Beach Erosion Board, as a part of its basic responsibility, will continue to seek and report on this type of publication which may not be readily available to U. S. personnel.

Annex II - Method of determining pressures of standing waves on types of vertical walls. (8 pages)

Annex III - Determination of the changes taking place in the parameters of wind waves as they enter partially protected areas. (15 pages)

Annex IV - Determination of changes in reservoir shores. (14 pages)

The manual, edited by Mr. Ye I. Dyshko, was compiled by the Interdepartmental Committee on Wave Effect on Hydrotechnical Construction and Shores, Academy of Sciences, USSR. It represents the joint effort of numerous oceanographic, engineering, transportation, and scientific agencies in the USSR with an interest in wave energy and the effects of waves. The data in the manual are for the guidance of all Soviet engineers engaged in work related to maritime and river construction and shore protection.

A translation of the Soviet manual is being made by the Beach Erosion Board and when completed will be available for study by interested personnel. In addition, the technical data will be analyzed and compared with that in its own Technical Report No. 4.

ICE FLOW PATTERNS ALONG THE DELAWARE COAST

The following photographs, submitted by Mr. Joe S. Robinson, Assistant Chief Engineer, Delaware State Highway Department, were taken on 7 February 1961. The drifting ice floes indicate some interesting flow patterns in the nearshore zone of the Atlantic Ocean. The most striking eddy-type formations were indicated just north of the jetties at Indian River Inlet and in front of and adjacent to the groins at Rehoboth Beach, at which locations some of the accompanying photographs were taken.

No attempt has been made to analyze or define the flow patterns. The photographs are being presented merely as an item of pictorial interest to the readers of the Bulletin.

In this area the predominant direction of littoral transport is northward toward Cape Henlopen. A substantial quantity of beach fill was placed on the shore north of Indian River Inlet in 1957, under a Federal-aid project to protect the shores from the inlet to and including Rehoboth Beach.

Photo 1 - Immediately North of Indian River Coast Guard Station

Photo 2 - Savage's Ditch - 1 1/2 miles north of Indian River Inlet

Photo 3 - Rehoboth Beach - between Henlopen Hotel and Rehoboth Avenue

Photo 4 - Rehoboth Beach at Rehoboth Avenue

Photo 5 - Rehoboth Beach - Henlopen Hotel

Photo 6 - North of Rehoboth Beach - Cochran Groin

Photo 7 - About 2 miles south of tip of Cape Henlopen

Photo 8 - Tip of Cape Henlopen - South Shore of Delaware Bay in background

PROGRESS REPORTS ON RESEARCH SPONSORED BY

THE BEACH EROSION BOARD

Compiled by Thorndike Saville, Jr., Research Division
Beach Erosion Board

Summaries of progress made during fiscal year 1961 (i.e. to June 30, 1961) on the several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements as to the status of some research projects being prosecuted in the laboratory of the Beach Erosion Board, are presented below. These summaries supplement and continue those contained in prior issues of the Bulletin.

1. University of California, Contract DA-49-055-eng-8. Sources of Beach Sand.

Seasonal sampling of the eighteen beaches in the San Francisco area was continued. The beaches between Russian River and the Oregon State line were also occupied several times during the year, so that the three critical times of the year (late summer, early winter, and late spring) might be represented. Reports on this work are underway. A rather extensive study was made of the feasibility of using the Frantz electro-dynamic separator for segregating beach sands into different mineral groups on the basis of their magnetic susceptibility. Both grain size and specific gravity have also proved to be important factors, and accordingly the development of proper techniques has been difficult, although considerable progress has been made.

II. Massachusetts Institute of Technology, Contract DA-49-055-eng-16. Sorting of Beach Sand by Waves.

A report "Equilibrium Characteristics of Sand Beaches in the Offshore Zone" has been prepared (Technical Memorandum No. 126 of the Beach Erosion Board). The report describes a theoretical and experimental investigation of equilibrium profiles and sediment sorting in the offshore zone, designed to test the applicability of existing idealized theories to the prediction of equilibrium characteristics of laboratory sand beaches. Two different sediment motion equilibrium criteria are considered; one in which the moments on a stationary particle are at equilibrium and one in which the particle is oscillating with no net motion. Results indicate existing theories provide good quantitative prediction of the seaward limit of profile modification and whether a given beach will build or erode under action of a given incident wave. Quantitative prediction of profile shape is good only near the offshore extreme of profile modification. Sorting experiments support qualitative theoretical predictions of increase in size sorting in the onshore direction and tendency toward formation of

bi-modal size-frequency distributions. The contract has been extended to study, both experimentally and analytically, the formation of littoral currents along straight beaches. Initial experiments involve wave-induced currents along a beach with a smooth impermeable 1 on 10 slope. The initial work has been to establish experimental techniques to maintain uniformity of flow along the test beach, and to measure satisfactorily wave height, elevation of mean water surface, and current velocities and distribution.

III. University of California, Contract DA-49-055-eng-17. Fundamental Mechanics of Sand Movement by Waves

A report "Sand Movement by Wind Action (on the Characteristics of Sand Traps)" was published as Technical Memorandum No. 119 of the Board. This report discusses the calibration of various types of sand traps in a wind tunnel; efficiencies of these various traps have been checked and compared with each other. As a result of the tests, a trap giving an efficiency close to 100 percent has been developed. Some field tests were made using this portable sand trap, during which the vertical velocity distribution was determined both with a bank of anemometers and a group of Pitot tubes. A report describing these tests is being prepared. Under that portion of the contract dealing with sand movement by waves, the model tests with three-dimensional roughness were concluded. Analysis of the data has shown that the velocity distributions are similar to those for smooth surface and two-dimensional roughness. However, attempts to relate the sediment transport rate to the shear stress obtained from integration of the velocity profile have so far been unsuccessful. A new approach similar to that for unidirectional flow is now being considered, wherein it is proposed to calculate the instantaneous lift force acting on the individual grain, and establish criteria of stability depending on the direction of the resultant of this force and the submerged weight of the grain.

IV. University of California, Contract DA-49-055-eng-44. Laboratory Study of Wave Refraction.

Ripple tank tests were completed on the refraction, reflection, and energy dissipation characteristics of a solitary wave at oblique incidence to an inclined beach. A report "Experimental Study on the Solitary Wave Reflection Along a Straight Sloped Wall at Oblique Angle of Incidence" was published as Technical Memorandum No. 124 of the Board. In these tests it was found that curved ripples developed when incident waves hit a wall with a slope less than approximately 65°. As the angle of incidence increased, an envelope of these ripples formed and became large enough beyond a certain angle of incidence, depending on slope, to look like a reflected wave but remained curved as were the ripples. For a relatively steep wall slope, larger than 65°, reflection was regular, but the angle of incidence at which a straight reflected wave occurred depended on the slope of the wall. For a wall with vertical or negative slope Mach reflection took place for wave incidence angles between 30° and 35°. Mach reflection ceased and regular

reflection occurred when the angle of incidence was 45°. This contract also partially supported some work on non-linear wave theory in shallow water, on which a report "Higher Approximation to Non-linear Water Waves and the Limitimg Heights of Cnoidal, Solitary, and Stokes' Waves" was prepared and issued in limited distribution as University of California IER Report, Series 89, Issue 6. This report presents higher order approximations, and determines limiting conditions for waves of various form. For example, the maximum limiting amplitude for the solitary wave is found to be 8/11 of the free water depth, and it is shown that Stokes' waves with the largest amplitudes are restricted to wave lengths less than 8.15 times the free water depth. Application of the theoretical results is also made to formulate rather severe limitations upon the hydraulic analogy between shallow water waves and isentropic perfect gas flow. Exploratory work in the ripple tank on refraction of wind-generated waves was also carried out, but considerable difficulty was observed in differentiating the effects of refraction from generation effects in the generating area.

V. Agricultural and Mechanical College of Texas, Contracts DA-49-055-eng-56-4, and 58-9. Estimation of Hurricane Surges.

Additional work was done on the research problem in Narragansett Bay (eng-56-4). Detailed computations of the sequence of water level and flow at various points and sections of the Narragansett Bay region were made utilizing an IBM 704 computer. This program incorporated the effect of longshore winds which had not been included in the previous 650 calculations. Following obtention of values for various possible design hurricanes for use in determining design criteria for possible hurricane protection for the Narragansett Bay region, the contract was considered completed. Computations made for storm surge estimates in the New York Harbor entrance area (eng-58-9) were summarized in a report "The Prediction of Hurricane Storm Tides in New York Bay" published as Technical Memorandum No. 120 of the Board. This report describes the effort made to correlate storm surges in New York Bay with the meteorological characteristics of the storms producing them, and thus to predict the nature of the storm surge resulting from the hypothetical design hurricane. The method used was largely empirical, but had theoretical guidance. Therefore, though the constants involved apply only to the specific areas studied, the general method and procedure may well have more general application. A discussion of the method presented was made by Mr. D. Lee Harris (Chief, Hurricane Surge Unit, U. S. Weather Bureau) in view of possible usage of the method by the Weather Bureau, in which he suggested a slightly alternative approach. This discussion, and the reply thereto by the author of the report (Dr. Basil Wilson, A& M College of Texas) were published as Technical Memorandum No. 120-A of the Board.

VI. Dr. W. C. Krumbein (Consultant). Study of Beach Sampling Methods.

The initial phase of a continuing program to determine the use of computer techniques to study the dominant factors influencing beach

characteristics and stability has been completed. Field data obtained at Mission Bay, California in 1950 were utilized in the study and found to be too few and too similar to develop clearly defined relationships. A method by which such data may be treated has been determined as a result of this study, and the design of a possible field test to acquire all necessary data is underway. The results of the computer study are being summarized and will be published as a technical memorandum in the latter part of 1961.

VII. Beach Erosion Board Laboratory.

(a) Wave Forces on Structures.

Analysis was continued on the wave force data obtained in the large wave tank on a vertical 12-inch diameter pile. This work has been pointed particularly towards the phase relationship of the water elevation, water velocity, and wave force with the passage of the waves. A report on this work is under preparation. A new section on wave forces on piles was prepared for inclusion in Beach Erosion Board Technical Report No. 4, making use of higher order approximations of wave characteristics. A somewhat more comprehensive treatment of this work is being put into report form.

(b) Wave Run-up.

Additional large-scale data involving waves up to 3.5 feet in height were gathered on a 1 on 1-1/2 riprap protected slope using 160-pound rock in an attempt to determine possible existence of a scale effect. Calibration tests for this tank were essentially completed, to enable accurate determination of the waves acting on the structure. Data on effect of scale in determination of prototype wave run-up from small-scale model tests on smooth stones were analyzed, and a correction curve prepared for inclusion in the new edition of Beach Erosion Board Technical Report No. 4. These data were also combined with run-up data, resulting in a corrected run-up curve for specific use with normal design waves in inland reservoirs. This curve is included in a report "Freeboard Allowances for Wind-Generated Waves in Inland Reservoirs" presented before the American Society of Civil Engineers, and submitted to them for publication.

(c) Study of Sand Bypassing Operations.

Efforts were continued to collect all available data on sand bypassing operations (past, present, or planned) for correlation and study. The hydrographic survey data obtained in the Port Hueneme area in June 1959 are now being analyzed. A field observation program was initiated in the vicinity of the new Ventura County Harbor, California, in which an offshore breakwater (parallel to the shore) forms a protected area serving as a sand trap. Sand deposited in this protected area is to be dredged and bypassed to the downdrift side of Port Hueneme. Wave gages for this study were installed, and tape recorders for use in obtaining material for wave

spectrum analyses to be made at the Board were supplied to the Ventura area. Study is continuing to determine the feasibility of adapting a radioactive source type density measuring instrument to be used with a velocity meter to measure quantity of material pumped in bypassing operations.

(d) Laboratory Study on Relation of the Littoral Drift Rate to Incident Waves.

A series of additional laboratory tests were made in the Shore Processes Test Basin to obtain further data on the relation of littoral movement to incident wave characteristics. A maximum movement rate of about 16,000 pounds of sand per hour (dry weight) was obtained with approximately 9-inch waves. A few tests have enabled comparison of littoral drift rates for the same average wave conditions, utilizing (1) waves of a constant period, and (2) waves varying plus or minus 10 to 15 percent about an average period. The indications are that the transport rate is greater for the waves with varying characteristics than for the waves of constant height and period. Additional work on this facet is planned for the following year. A report discussing the tests and results through 1959 was in preparation and essentially completed. A new feeding mechanism for introducing sand at the updrift end of the test beach was developed and tested; a description of this equipment is contained in this Bulletin. Work has also continued in an attempt to relate measured net quantities of littoral accumulation at several points on the North Atlantic coast to wave energy derived from statistical hindcast wave data. A report summarizing this work is in preparation.

(e) Measurement of Suspended Material in Laboratory Wave Tanks.

Additional suspended sediment samples were obtained utilizing a pump-type sampler in a wave flume using lower specific gravity coal rather than sand . It is hoped that these measurements may aid in defining scale relations between model and prototype measurements. Comparison is to be made with measurements of sand in suspension under the same wave conditions, and with waves scaled up according to the settling velocity of the sediment.

(f) Wave Theory

Work has continued on basic wave theory with particular emphasis on determination of design wave criteria. A report "A One Dimensional Gravity Wave Spectrum" was presented at the NSF-ONR sponsored conference on wave spectra and is being published in their Proceedings. This paper describes the wave spectrum system, its meaning, and use. A further report "A Theory for Waves of Finite Height" was published in the Proceedings of the Seventh Conference on Coastal Engineering. The latter report presents an exact theory, which may be extended to any order. It is represented by summation in harmonic series, each term of which is in an expanded form. The terms of the series when expanded result in an approximation of the exact theory,

and this approximation is identical to Stokes' wave theory extended to the same order. The theory represents the irrotational divergenceless flow. Work also has been under way on preparation of a table of the values of coefficients used in this theory.

(g) Equilibrium Profile and Model Scale Effect Studies.

Testing was continued in a small tank utilizing low specific gravity material (crushed coal) to study the effect of scale on movable bed models under wave action. The specific gravity of the coal was chosen so as to model the settling velocity of the sand used in the large-scale tests. Profiles derived from these tests bear basic resemblance to the profiles obtained with the large (up to 5.5-foot) waves on a sand beach, although things seem to happen sooner than expected in the small-scale tests.

(h) Rubble Mound Stability.

Large-scale (7.5 to 1) tests on stability of rubble-mound structures under wave action were continued to spot check the results of the small-scale test program at the Waterways Experiment Station. Previous tests have involved entirely non-breaking waves. Since it was felt that somewhat greater damage might be caused by fully breaking waves having the same incident deep water height as the non-breaking waves, a 1 on 10 concrete beach slope was installed in front of the test breakwater to permit generation of a breaking wave on the breakwater base. These tests were carried out for the 1 on 1-1/2 slope rubble breakwater using approximately 1-foot diameter, 160-pound stone. The tests did show that initiation of damage to the breakwater occurred with breaking waves having smaller offshore heights than for the non-breaking waves. Calibration of the tank to obtain a precise determination of the wave heights at the structure location without the structure in place has been carried out and is essentially completed. Complete analysis of the data obtained on rubble mound stability must await completion of these calibration tests. The next tests will utilize a four-legged concrete shape, a quadripod. This shape is somewhat similar to a tetrapod with a flat base. A supply of these (weight, 75 pounds each) has been contracted for, and is currently being delivered.

(i) Wave Measurements and Analysis.

Wave records continue to be taken at the five ocean gage stations (Atlantic City, New Jersey; Palm Beach and Naples, Florida; Huntington Beach and Port Hueneme, California). The gage at Naples was destroyed during Hurricane Donna in September 1960, but has been replaced. Additional tape recorded wave data for both Atlantic City and Port Hueneme were obtained and further spectral analyses of some of these were made on the analyzer. Manual and computer computation of the spectra for some of these were continued for comparison with those obtained from the analyzer. A report describing the spectrum analyzer, its uses, and the analyses presented by it was completed, and presented at an NAS-ONR conference on wave spectra. A study has been

carried out on the interpretation of the analyzer analysis, and a report is being prepared for users of this analyzer. Arrangements were also made for installation of a tape recorder on one of the offshore drilling platforms for the California Oil Company in the Gulf of Mexico to obtain data for spectrum analysis. Arrangements were initiated for a wave gage installation on the new Coast Guard tower off Buzzards Bay which is being constructed as a replacement for an offshore lightship. This gage is under construction, and will be somewhat unique in that it is a double-range type gage, having a range of 0-15 feet in 4-inch increments and a range of 0-45 feet in 1-foot increments. The gage will be programmed to obtain a record from each range every 30 minutes. Drafting of a report on the design, construction, calibration, and use of the various wave gages of the Board was continued. This report will include a description not only of the normal pressure gage, and fresh and salt water staff gages, but also a new type staff gage designed for use in estuaries and bays subject to fresh water flow where accurate measurements are needed over a wide range of salinities.

(j) Regional Studies.

A report "Geomorphology of the South Shore of Long Island, New York" has been prepared (Technical Memorandum No. 128). This report presents a discussion of the geologic factors which have influenced the development of the south shore of Long Island and includes a graphic presentation of the shoreline history. All readily available survey data and comparative volumetric changes are tabulated in appendices. Compilation of geomorphological and littoral material data for the coastal sector from Cape Henlopen, Delaware to Cape Charles, Virginia is under way, as is compilation of geomorphological data for the Atlantic coast of Georgia and Amelia Island, Florida, and the Gulf Coast of Florida from the Suwannee River to the Alabama State line.

(k) Technical Report No. 4, "Shore Protection Planning and Design".

A continuing study is being made to improve and supplement present chapters of this publication. Preparation of revisions and addenda were completed, and the draft of a reprint edition was reviewed and approved by members of the Beach Erosion Board. This new edition has gone to press, and publication is expected in the early fall. (Availability of this reprint publication is indicated elsewhere in this Bulletin.) Major revisions and additions involve sections on wave run-up, hurricane waves and surge, design criteria for rubble mound stability, and wave forces on piles.

(l) Re-examination of Beach Protection Projects.

A continuing program is being carried out on the re-examination of artificially nourished beaches to determine the effectiveness of the fill material within the beach zones, and to better establish the factors upon which the desired characteristics of fill material are based. Continuing studies of other projects constructed following Beach Erosion Control

studies are under way to determine effectiveness of the various structure components. A report "Behavior of Beach Fill and Borrow Area at Prospect Beach, West Haven, Connecticut" has been prepared (Technical Memorandum No. 127). This report analyzes comparative survey and sample data to determine the behavior of beach fill obtained from an offshore borrow source. Beach fill projects in Connecticut (other than Prospect Beach), New Jersey, Delaware, Florida, Pennsylvania and California were under study this fiscal year.

(m) Experimental Studies of the Effectiveness of Sand Fences.

In cooperation with the State of North Carolina and the Wilmington District of the Corps of Engineers a study has been initiated on Core Bank, one of the Outer Banks of North Carolina, on the effectiveness of various types of sand fence in building and stabilizing dunes. A series of 1,000-foot sections of various types and arrangements of sand fence have been installed on Core Bank, and periodic examinations and surveys are made to obtain information on the comparative effectiveness of the various sections. A self-contained wind measuring instrument has been installed in the test area to obtain information on wind velocity during the experiment.

(n) Model Determination, Scour at Toe of Seawalls.

A study has been initiated in the Shore Processes Test Basin in an attempt to experimentally relate the depth and lateral extent of scour at the toe of seawalls to incident wave and beach sediment characteristics. Waves are generated perpendicular to a vertical seawall located initially at the still water level, and the development of the scour hole is measured. Several wave conditions have now been tested for two sand sizes (0.2 and 0.4-mm median diameter). Although the program has involved so far only a vertical wall, located at the still water level, other types of walls and locations relative to still water level are planned for future tests.

(o) Hurricane Studies.

The staff of the Board has continued to support the hurricane study work of the Corps of Engineers. Considerable work has been done by the staff in developing and improving simplified methods for estimating storm surge elevations and wave heights under a variety of shoreline conditions. Wave forces, and wave run-up and overtopping phenomena connected with seawall, dike, and barrier design under hurricane conditions have also been studied. A generalized study of the effect of offshore slope on the amount of wave set-up observed with high hurricane waves has continued. The test results have been summarized in a report "Experimental Determination of Wave Set-up" delivered at the 2nd Technical Conference on Hurricanes at Miami Beach, Florida. In general the tests have indicated a wave set-up at the shore line of about 10 to 15 percent of the wave height for beach profiles of 1 on 15 slope and less, with little or no set-up at the shore line for slopes steeper than about 1 on 6. A number of tests have also

been made with an offshore barrier with top elevations at or slightly below the still water level. These tests indicate considerably higher wave set-up, the presence of the barrier sometimes doubling the set-up at the shore line. However, these tests involved a barrier across the entire width of the wave tank, and so did not permit any lateral flow out of the area of increased water level, as would probably occur in nature. Consequently, this indicated barrier effect is possibly considerably exaggerated.

VIII. Publications

Technical Memoranda published by the Board during fiscal years 1960 and 1961 are listed below. Copies can be furnished on request to persons within the United States to the extent of a limited printing.

T.M. No.	Title and Date
	F.Y. 1960
*116	On the Theory of the Highest Waves, July 1959.
117	The Damping of Oscillatory Waves by Laminar Boundary Layers, August 1959.
*118	Wave Variability and Wave Spectra for Wind-Generated Gravity Waves, August 1959.
	*Now out of print.
	F.Y. 1961
119	Sand Movement by Wind Action (On Characteristics of Sand Traps), August 1960.
120	The Prediction of Hurricane Storm-Tides in New York Bay, August 1960.
120-A	Discussion of Technical Memorandum No. 120 (and Closure by Author), April 1961.
121	Development and Tests of a Radioactive Sediment Density Probe, September 1960.
122	Effects of Reefs and Bottom Slopes on Wind Set-up in Shallow Water, November 1960.
123	Transient Wind Tides in Shallow Water, January 1961.
124	Experimental Study on the Solitary Wave Reflection Along a Straight Sloped Wall at Oblique Angle of Incidence, March 1961.
125	On the Description of Short-Crested Waves, March 1961.

Material covered by the Technical Memoranda listed above is briefly described in the foregoing paragraphs (1 to VII) Research Progress or in the section on Research Progress in volume 14, July 1960, of the Annual Bulletin of the Beach Erosion Board.

TECHNICAL REPORT No. 4
SHORE PROTECTION PLANNING AND DESIGN

A reprinting of the Beach Erosion Board's Technical Report No. 4, Shore Protection Planning and Design with revisions current to May 1961, will be available in October 1961. The supply of the original report printed in 1954 was exhausted in 1958. Continued demand has indicated the need of reprinting. This report is a comprehensive compendium of available knowledge for solution of coastal engineering problems, and contains a summary of applicable methods, techniques and pertinent data useful to both practicing and research engineers. It is also suitable as a text book for the teaching of coastal engineering subjects.

This report may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. at $3.00 per copy in the United States. Foreign orders should include $0.75 additional to cover postage.

BEACH EROSION STUDIES

Beach erosion control studies of specific localities are usually made by the Corps of Engineers in cooperation with appropriate agencies of the various States by authority of Section 2 of the River and Harbor Act approved 3 July 1930. By executive ruling the costs of these studies are divided equally between the United States and the cooperating agencies. Information concerning the initiation of a cooperative study may be obtained from any District or Division Engineer of the Corps of Engineers. After a report on a cooperative study has been transmitted to Congress, a summary thereof is included in the next issue of this Bulletin. Summaries of reports transmitted to Congress since the last issue of the Bulletin and lists of completed and authorized cooperative studies follow.

SUMMARIES OF REPORTS TRANSMITTED TO CONGRESS

SAN DIEGO COUNTY, CALIFORNIA

The purposes of the investigation were to determine the causes and most suitable methods of controlling erosion of the shores of San Diego County, California. An interim report on the same shores (B.E.B. Bulletin, Vol. 10, 1956) considered the more urgent problems at Oceanside, Ocean Beach, Imperial Beach, and Coronado. This study also included, as directed by Congress, a survey of Camp Pendleton Harbor and Oceanside, California with a view to determining the extent of Federal aid which should be granted toward recommended beach erosion control measures at Oceanside in equity without regard to limitations of Federal law applicable to beach erosion control.

San Diego County is in Southern California immediately north of the Mexican boundary. Its Pacific Ocean shore line, extending in a general north-south direction, is about 75 miles long. The coastal area consists generally of a series of long narrow beaches backed by bluffs and steep hills, except that at Mission and San Diego Bays it consists of low sandy peninsulas separating the ocean from those bays. The coastal area of the northern half of the county is drained by short, steep, intermittent streams. In the southern half, the drainage was formerly into Mission and San Diego Bays, except for the Tia Juana River which discharges into the ocean about 1-1/2 miles north of the Mexican border. Since 1951 San Diego River discharges directly into the ocean through a separate flood channel adjacent to the entrance to Mission Bay.

The City of Oceanside with a population of about 20,500 is in the northern part of San Diego County about 18 miles south of the north county line. It has an ocean frontage of about 3 miles, characterized by bluffs 20 to 40 feet high fronted by a narrow beach. Of the shore frontage requiring protection, a section about 10,000 feet in length is owned by the city; the remainder is privately owned. The center of Oceanside is about 2 miles south of the entrance to the Federal (Navy Department) harbor at Camp Pendleton. That harbor consists of an inner basin 20 feet deep. Jetties at the entrance were built in 1943 and the north jetty was extended southward to overlap the

south jetty in 1958. The problem at Oceanside is one of shore recession due to impoundment of the dominant southward littoral drift at the harbor jetties. An existing Federal beach erosion control project provides for artificial placement of beach fill on the Oceanside frontage. Although this fill was partially placed in 1957-58 in connection with dredging Camp Pendleton Harbor, erosion of the fill has been rapid because of the deficiency of natural supply of material, and because reconstruction of jetties at Camp Pendleton Harbor provided additional protected area for local impoundment of beach material. Additional measures are desired to restore and maintain an adequate protective and recreational beach along the city frontage.

Ocean Beach, a part of the City of San Diego, is a short pocket beach between the Mission Bay - San Diego River jetties and Sunset Cliffs. An existing Federal beach erosion control project provided for placement of beach fill in connection with dredging of the Federal navigation project for Mission Bay and construction of one groin. This work was completed in 1955. No further work is required at this time. Imperial Beach is a residential community on the ocean shore about 3.5 miles north of the Mexican border. An existing Federal project provides for construction of five groins on this shore frontage. The most northerly groin was constructed in 1959 in accordance with the program of progressive construction from north to south. This construction resulted in widening of the beach and indicates that completion of the project will provide a satisfactory protective and recreational beach.

The tides on the ocean shore of the study area have a diurnal inequality, the mean and diurnal ranges being respectively about 3.7 and 5.3 feet. The maximum tide each year is about 7 feet above mean lower low water. Characteristic waves are swells generated in distant ocean areas. They have heights up to 10 feet and periods up to 20 seconds, with the greater heights and shorter periods occurring in the winter. Winter waves generally approach the shore from upcoast of normal, summer waves frequently approach from downcoast of normal. On the ocean shores north of Point Loma at the entrance to San Diego Bay, littoral drift is in general southward in winter and northward in summer. In the Oceanside area southward drift is predominant, as indicated by the general accretion north of the Camp Pendleton Harbor jetties and erosion to the south. At Mission Beach and Ocean Beach the net annual movement in either direction is negligible. South of Point Loma, the predominant direction of drift is northward. At all ocean front areas there is also a large seasonal onshore-offshore movement of material.

The District Engineer concluded that localities which have had erosion problems warranting remedial action are included in authorized Federal projects; that the project for Ocean Beach being completed is serving effectively at this time; and that the project for Imperial Beach is partially completed and will apparently be continued to effective completion in accordance with the project plan. He further found that certain modifications are necessary in the existing project for Oceanside in order to provide for changed conditions since the project was adopted and to revise the Federal contribution toward the cost on the basis of equity.

The District and Division Engineers and the Beach Erosion Board concluded that the modified plan of shore protection for Oceanside should provide a protective beach 200 feet wide for about 13,000 feet between Camp Pendleton Harbor and Witherby Street and 100 feet wide for about 4,500 feet south of Loma Alta Creek by artificial placement of approximately 2,200,000 cubic yards of suitable sand, including 500,000 cubic yards of sand as advance nourishment, and a groin about 800 feet long near the north limit of the fill to prevent future loss by impoundment within the harbor area. Periodic nourishment of the beach fill would be accomplished by artificial placement of sand in connection with maintenance dredging of the navigation channels at Camp Pendleton Harbor and the proposed civilian small-craft harbor, at no cost to the project. They made an economic analysis of the modified plan for Oceanside and concluded that the modified plan is justified by prospective benefits, that the erosion has been caused by construction of Camp Pendleton Harbor by the United States as a wartime measure, without provisions for preventing damage to adjoining shores, and that in equity the restoration of beach conditions existing prior to harbor construction should be a Federal responsibility. They accordingly recommended adoption of a project in lieu of the authorized project at Oceanside to provide a protective beach generally 200 feet wide by 13,000 feet long north of Witherby Street and generally 100 feet wide by 4,500 feet long south of Loma Alta Creek, and to provide a stone groin about 800 feet long near the north limit of the fill. They also recommended, subject to certain conditions, that the total first cost of the work be borne by the United States, but that the cost of maintaining the groin be borne by local interests.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board and further recommended that any material dredged in connection with Camp Pendleton Harbor or any subsequently developed civilian harbor in the area be used for nourishment of the Oceanside beach, and subject further to the condition that local interests agree that the cost allocated to this beach protection project shall be adjusted to reflect the savings from multiple-purpose construction of the addition of the contemplated Oceanside harbor improvement to the over-all project, if authorized, and the cost so transferred from the Beach erosion project to the harbor project be shared by local interests and the Federal Government as appropriate for small-boat harbor projects.

AMELIA ISLAND (FERNANDINA BEACH), FLORIDA

The purpose of the investigation was to determine the most satisfactory method of restoring and preserving the beach for protection of existing structures and for recreational use. Amelia Island is in Nassau County in the northeast corner of Florida, about 20 miles north of Jacksonville. The island is about 13 miles long between St. Marys River on the north and Nassau Sound on the south. The City of Fernandina Beach is near the north end of Amelia Island. The 1950 populations of Fernandina Beach and Nassau County were respectively about 4,400 and 12,800. Although summer increases in population have been small, the trend is toward more summer resort activity

as accomodations are expanded. Fort Clinch State Park occupies a shore frontage of about 4,000 feet immediately south of St. Marys River entrance. The study area extends about 5 miles south of the jettied mouth of St. Marys River to the fishing pier. The Fort Clinch State Park beach is backed by high dunes. The shore of the problem area, which begins south of the park, is generally low with residential development immediately back of the berm. The problem is one of gradual erosion of the shore throughout the latter area. This erosion has resulted in damage to roads and buildings as the protective beach was reduced in width.

The tides at Amelia Island are semi-diurnal, with mean and spring ranges of 5.7 and 6.7 feet respectively. Waves affecting the shore approach principally from the northeast quadrant resulting in southward predominance in direction of littoral drift, as indicated by past accretion at the St. Marys River north jetty. However, reversals in drift direction cause some accumulation of sand in a fillet south of the south jetty. Due to the relatively low top elevation and permeability of this jetty sand is carried over or through the jetty into the inlet.

The District and Division Engineers and the Beach Erosion Board concluded that the most suitable complete plan of protection comprises a protective beach about 13,000 feet long and a groin about 800 feet long near the north limit of the fill. The protective beach with a berm 50 feet wide at elevation 11 feet above mean low water would be provided by artificial placement of approximately 300,000 cubic yards of suitable sand for the initial fill and 600,000 cubic yards of sand as advance nourishment. Periodic nourishment of approximately 200,000 cubic yards of sand per year would be required to maintain the widened beach. They made an economic analysis of the foregoing complete plan of protection and found it to be not justified by evaluated benefits. They also considered a partial protection plan comprising construction of one groin and placement of spoil from maintenance dredging of the Fernandina Harbor entrance channel on the beach about 4,000 feet south of the south jetty. They estimated that this plan would involve placement of about 120,000 cubic yards of sand annually. Although they believed that this plan would reduce the rate of erosion, they did not evaluate the benefits therefrom which were considered to be relatively small.

The District and Division Engineers and Beach Erosion Board concluded that the cost of protecting the beach of Amelia Island by either plan exceeds the benefits that could be reasonably expected by a wide margin, and recommended that no project be adopted by the United States at this time authorizing Federal participation in the costs of shore protection at Amelia Island, Florida. They further recommended that, subject to their own determination of economic justification, local interests consider adoption of the complete plan of protection comprising beach widening, construction of one groin and periodic nourishment, or as a minimum construct one groin and arrange to have dredged material placed on the beach periodically and pay such costs as may be involved in excess of the costs of disposal by other means. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

PALM BEACH COUNTY, FLORIDA

(from Martin County line to Lake Worth Inlet and from South Lake Worth Inlet to Broward County line)

The purpose of the investigation was to determine the most economical method or methods of restoring the beaches and shore property from future erosion. The study area comprises two reaches of shore totalling 29.3 miles on the east coast of Florida from the Martin County line to Lake Worth Inlet and from South Lake Worth Inlet to the Broward County line. A study of the intervening reach was completed in 1957 (B.E.B. Bulletin - Vol. 12, 1958). The area is centered about 70 miles north of Miami. Parts of the area are extensively developed as winter resorts. The permanent population of the county, about 157,000, is greatly increased during the winter. About 2.4 miles of the ocean shore are publicly owned, most of which is used for public bathing beaches. The shore of the study area is exposed to waves of the Atlantic Ocean. To the northeast the fetch is unlimited, but to the east and southeast the incidence of swells is influenced by the shelter afforded by the islands of the Bahama group. The predominance of energy components is such as to produce a dominant southward littoral transport. However, reversals in direction of transport occur, principally in the summer. The mean and spring tidal ranges are respectively 2.8 and 3.3 feet. The two highest tides of record, 11.2 and 8.7 feet above mean low water, occurred during hurricanes in 1928 and 1936 respectively. A tide of 7 feet is considered suitable for design purposes, as a tide of this height could be expected during hurricanes of medium intensity. The only apparent natural source of littoral material to supply the problem areas is the eroding beaches to the north. The accumulation of sand north of Lake Worth Inlet indicates a littoral drift rate of about 230,000 cubic yards annually.

The District and Division Engineers concluded that the most practicable plan of shore protection consists of artificial placement of protective and recreational beaches. Continued operation of the existing sand-transfer plant at South Lake Worth Inlet and additional periodic nourishment by artificial placement of suitable material from adjacent waterways would provide for stability of the protective beaches. They made economic analyses of the foregoing plan of protection by sections, and concluded that the plans of protection are economically justified for all reaches studied. They found that public benefits justify Federal aid of one-third of the first and periodic nourishment costs for the publicly owned shores, and that public benefits for certain privately owned reaches of shore justify Federal aid for those reaches.

The District and Division Engineers and the Beach Erosion Board recommended adoption of projects for Palm Beach County, Florida to authorize Federal participation in the costs of the plans for protection of the shores between Martin County and Lake Worth Inlet and between South Lake Worth and Boca Raton Inlets comprising restoration of a protective beach to a general width of 100 feet with a berm elevation of 10 feet above mean low water and

subsequent periodic nourishment thereof including operation of the sand-transfer plant at South Lake Worth Inlet for a period of 10 years from the year of completion of the initial placement, substantially in accordance with the plan developed by the District Engineer, with such modifications thereof as may be considered advisable by the Chief of Engineers. Federal assistance would entail contribution of funds toward the initial construction costs of the beach restoration and of the costs of periodic nourishment for a period of 10 years in amount of 3.2 percent for the Martin County-Jupiter Inlet segment, 7.7 percent for the Jupiter Inlet-Lake Worth Inlet segment and 3.4 percent for the South Lake Worth Inlet-Boca Raton Inlet segment.

The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

DELAWARE BAY COAST OF NEW JERSEY

(Cape May Canal to Maurice River)

The purpose of the investigation was to develop the most suitable plans for restoration and protection of the problem areas. The study area is in Cape May and Cumberland Counties, New Jersey. It comprises the Delaware Bay shore from the entrance of Cape May Canal to the mouth of Maurice River, a shore length of about 22 miles centered about 70 miles southeast of Philadelphia, Pennsylvania. A narrow strip of the coast, principally between Cape May Canal and Bidwell Ditch, is developed to a minor extent as a summer resort area. The estimated permanent population of the shore communities is about 3,200 and the summer population is about 23,300. About 10 percent of the shore frontage is publicly owned, but it is not developed for public use. The shore from Bidwell Ditch to Cape May Canal, approximately 11 miles long, is oriented north to south. It is characterized generally by low banks, narrow beaches and offshore mud flats. Accretion of sand has occurred north of the Cape May Canal and south of the Bidwell Ditch jetties at the ends of this section. North of Bidwell Ditch to West Creek, a distance of 4 miles, the shore is concave. It is undeveloped and fronts marsh land. West of West Creek, a frontage of about 7 miles to and including East Point, the shore is oriented generally from east to west. It consists generally of sandy beaches with scattered houses fronting marsh land. Tides in Delaware Bay are semi-diurnal, their mean range being 4.7 feet at Cape May Point and 5.7 feet at East Point near the mouth of Maurice River. The maximum tide of recent record was about 10 feet above mean low water at East Point. Storms in Delaware Bay are the sole cause of important wave action. Accretion at the Cape May Canal north jetty and the Bidwell Ditch south jetty indicates littoral transport in both directions along that section of shore, with possibly some northward predominance. From East Point to Dennis Creek, the littoral transport probably has a slight eastward predominance. Rates of movement and loss are apparently low.

The District and Division Engineers and the Beach Erosion Board concluded that the most suitable plans of protection for the several problem

areas comprise placement of beach fill, supplemented in certain cases with planting of dune grass and periodic nourishment of the beach. They further found that the public benefits of the work would be insignificant, and therefore made no determination of economic justification. They recommended that no project be adopted authorizing Federal participation in any beach erosion control measures for the area, and that no share of the cost of constructing any improvement be borne by the United States. They further recommended that any beach erosion control measures which may be undertaken by local interests, based upon their own determination of economic justification, be accomplished in accordance with the plans proposed in this report. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

SHORE LINE OF LAKE ERIE FROM OHIO-MICHIGAN STATE LINE TO MARBLEHEAD, OHIO

The purposes of the investigation were determination of methods and costs for protecting the shores of the study area and appropriate changes in recommendations contained in the Beach Erosion Board's 1944 report on this area (B.E.B. Bulletin, Vol. 1, No. 1, 1947) and development of specific plans and estimates of their costs for restoration and protection of publicly owned shores at Metzger Marsh, Crane Creek State Park, the area opposite State Highway No. 2 west of Port Clinton, and East Harbor State Park. The area studied is located all within Lucas and Ottawa Counties, except for Kelleys Island in Erie County, on the south shore of Lake Erie north and east of Toledo, Ohio. It includes the north and south shores of Maumee Bay at the western end of Lake Erie, the westernmost 35 miles of the south shore of Lake Erie between Little Cedar Point and a point about 1/2 mile east of Marblehead Light, and offshore islands, North Bass, Middle Bass, South Bass and Kelleys Islands. Toledo Harbor and Channel, Port Clinton at the mouth of Portage River, and Put-in-Bay on South Bass Island, have all been improved by the United States for navigation.

A population of over 3-1/2 million resided within a 60-mile radius of the study area in 1950 and the larger metropolitan areas have shown increases of over 20 percent to 1959. Toledo is adjacent to the study area and Detroit, Michigan lies within the 60-mile radius. Where property along the shore line has been developed, it has been mainly for private residential or recreational purposes. Extensive commercial development has taken place near the mouth of Maumee River at the extreme western end of the study area. The City of Toledo owns shore frontage at Bay View Park near the mouth of Maumee River and the City of Port Clinton owns Lakeview Park immediately east of the mouth of Portage River. The State of Ohio owns shore areas at Metzger Marsh, Crane Creek State Park, Camp Perry and a half-mile stretch of beach fronting State Highway No. 2, all west of Port Clinton, and at Catawba Island and East Harbor State Parks to the east thereof. The State also owns waterfront property on the western shore of South Bass Island and about 500 feet of shore on the north shore of Kellys Island. There is Federally owned shore frontage at the Erie Proving Grounds Reservation west of Camp Perry and at a small National Park area near the neck of South Bass Island, the latter being the location of Perry's Victory Memorial Monument. A small public bathing beach owned by

the village of Put-in-Bay adjoins the Federal park. The marshy areas west of Port Clinton are used extensively for hunting and trapping. Pollution is not a problem at any of the bathing beaches within the study area. Studies in 1956 indicated the Lake Erie waters in this region to be of good quality for swimming or other recreational purposes.

The mainland shore under study consists principally of low-lying marshy or reclaimed marsh areas fronted by low barrier beaches composed of fine sand. The west shore of Catawba Island and the shore between East Harbor and Marblehead Light are comprised of glacial till or rocky bluffs with coarse pebble or cobble beaches at indentations. Shores of the offshore islands are of rugged nature, consisting of cliffs for most of the islands' perimeters. Maumee and Portage Rivers are the principal rivers draining into Lake Erie through the study area, but neither contributes any substantial amount of beach material to the Lake Erie shore. Several other minor streams and drainage canals also reach Lake Erie through the shores of the study area. West of Locust Point, wider beaches have accumulated to the east of structures at the creek mouths, while east of Locust Point wider beaches appear to the west of structures. A large sand bar extends northwest from Little Cedar Point across the Maumee Bay entrance. Material supplying the bar and beaches is derived chiefly from erosion of adjacent shores, but throughout the entire area there is a scarcity of littoral drift. Excepting rocky headlands on the mainland and the offshore islands, the entire study area has a history of erosion. In many places the natural barrier beaches have been breached and are deteriorating under wave action. Matzger Marsh is open to Lake Erie even at normal lake stages. Reno Beach and Howard Farms, east of Little Cedar Point, are protected by a lake shore earth levee constructed by the two communities. This levee has been breached and repaired at various times. An authorized Federal project for flood control at this location has not yet been built. Miscellaneous groins, bulkheads, and revetments have been erected in attempts to stabilize the shore, but have been only partially effective. The scarcity of natural littoral drift material precludes the formation of adequate beaches by groins alone. Six steel sheet pile groins varying in length from 109 to 187 feet and spaced 300 feet apart were constructed by the State of Ohio in 1958 at Crane Creek State Park.

The mean lake level for the months of April to November is about 1.8 feet above the established low water datum of elevation 570.5 feet. The highest lake stage and the highest monthly mean recorded at Toledo, Ohio, are respectively about 6.5 and 4.2 feet above low water datum. Storms cause sharp changes in lake levels as winds move the water toward the ends of the lake. The greater fetch and movement of winds affecting the area are from the northeasterly direction, and because the area is near the western end of Lake Erie, it is estimated that, considering the effect of wind setup during easterly storms, the lake could reach a level in the study area of about 6 feet above low water datum with a frequency of at least once in 20 years. During a northeast storm waves may range up to 8 or 9 feet in height in deep water with annual frequency, but ordinarily waves of this height would break before reaching shore structures. Natural beach berm heights in the study area range from 5 to 9 feet above low water datum. Existing

groins with shore ends from about 6 to 11 feet above low water datum indicate that these elevations are generally adequate to impound a low protective beach where a supply of sand by littoral drift is available. Along the low marshy shores of the study area, dikes or barrier beaches provide the only protection to the landward areas from storm-wave action of Lake Erie. Protection against wave action should extend to a height of 10 feet above low water datum to assure prevention of damaging overtopping. For the remainder of the study area where resistant bluffs exist alongshore, no further protection is needed. Ice forms a protective coating over beaches during winter months, but the lifting and battering action of shifting ice floes during the spring breakup must be considered in designing shore structures for structural stability.

The District and Division Engineers developed plans for protecting and improving the shores of the study area as follows:

a. Metzger Marsh - An earth levee along the north and east sides of the State-owned property with top width about 10 feet at elevation 580.5 feet (10 feet above low water datum) and lakeward slope covered with a 3-foot layer of riprap.

b. Crane Creek State Park - Restoring a sand barrier beach along 17,800 feet of State-owned property by placement of sand fill to a 50-foot berm width at elevation 579.5 feet (9 feet above low water datum) sloping upward to elevation 580.5 feet at the parking lot, and construction of 36 groins (6 of which have already been built but require landward extensions), spaced at 500-foot intervals and extending lakeward about 300 feet, to retain the fill.

c. State Highway Frontage Near Port Clinton - Providing a protective sand beach or a stone revetment.

The District and Division Engineers considered the jetty proposed by the State of Ohio at the navigation entrance to East Harbor. They concluded that it should be built to an alternative alignment, that is, northeasterly rather than easterly as proposed by the State, and extended farther lakeward (to the 4-foot depth contour) in order to better control entrapment of littoral drift and protect the entrance from storm waves from the northwest quadrant.

The District and Division Engineers found that restoration and protection of the beach at Crane Creek State Park are justified by evaluated benefits, and further found that the nature and amount of benefits warrant Federal participation in the construction of considered improvements at Crane Creek State Park.

The Beach Erosion Board recommended that project be adopted by the United Stated authorizing Federal participation by the contribution of Federal funds in amount of one-third of the first costs of measures for the restoration and protection of the shore at Crane Creek State Park, Ohio, substantially in

accordance with the following plan of the District and Division Engineers, with such modifications thereof as may be considered advisable by the Chief of Engineers:

> Restoring a sand barrier beach by placement of suitable sand fill along 17,800 feet of shore to a 50-foot width at elevation 579.5 feet (9 feet above low water datum) and construction of 36 groins spaced generally at 500-foot intervals and extending lakeward about 300 feet (construction of 26 of the groins to be deferred pending determination of the need thereof.)

The Board further recommended Federal participation in amount of one-third of the periodic nourishment costs for the section in which groin construction is deferred and for the period of such deferral. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

COMPLETED COOPERATIVE BEACH EROSION STUDIES

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
ALABAMA					
Perdido Pass (Alabama Pt.)	18 Jun 54	274	84	Unfav.	
CALIFORNIA					
Santa Barbara - Initial	15 Jan 38	552	75	Unfav.	
Suppl.	18 Feb 42				
Final	22 May 47	761	80	Unfav.	
Ballona Creek & San Gabriel R. (Partial)	11 May 38			Unfav.	
Orange County	10 Jan 40	637	76	Unfav.	
Coronado Beach	4 Apr 41	636	77	Unfav.	
Long Beach	3 Apr 42			Unfav.	
Mission Beach	4 Nov 42			Unfav.	
Pt. Mugu to San Pedro BW	27 Jun 51	277	83	Fav.	3 Sep 54
Carpinteria to Pt. Mugu	4 Oct 51	29	83	Fav.	3 Sep 54
Oceanside, Ocean Beach, Imperial Beach & Coronado, San Diego County	26 Jul 55	399	84	Fav.	3 Jul 58
Santa Cruz County	13 Sep 56	179	85	Fav.	3 Jul 58
Humboldt Bay (Buhne Pt.)	29 Mar 57	282	85	Fav.	3 Jul 58
Newport Bay to San Mateo Creek, Orange County	3 Dec 59	398	86	Fav.	14 Jul 60
San Diego County	30 Jun 60	456	86	Fav.	29 Mar 61
CONNECTICUT					
Compo Beach, Westport	18 Apr 35	239	74	Unfav.	
Hawk's Nest Beach, Old Lyme	21 Jun 39			Unfav.	
Ash Crk. to Saugatuck R.	29 Apr 49	454	81	Fav.	17 May 50
Hammonasset R. to East R.	29 Apr 49	474	81	Fav.	3 Sep 54
New Haven Hbr. to Housatonic R.	29 Jun 51	203	83	Fav.	3 Sep 54
Conn. R. to Hammonasset R.	28 Dec 51	514	82	Unfav.	
Pawcatuck R. to Thames R.	31 Mar 52	31	83	Unfav.	
Niantic Bay to Conn. R.	11 Jul 52	84	83	Unfav.	3 Sep 54
Housatonic R. to Ash Creek	12 Mar 53	248	83	Fav.	
East R. to New Haven Hbr.	15 Nov 55	395	84	Fav.	3 Jul 58
Saugatuck R. to Byram R.	14 Nov 56	174	85	Fav.	3 Jul 58
Thames R. to Niantic Bay	17 Jun 57	334	85	Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	PUBLISHED IN CONG.	FEDERAL PROJECTS RECOMMENDATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
DELAWARE					
Kitts Hummock to Fenwick Is.	11 Feb 57	216	85	Fav.	3 Jul 58
FLORIDA					
Blind Pass (Boca Ciega)	1 Feb 37	187	75	Unfav.	
Miami Beach	1 Feb 37	169	75	Unfav.	
Hollywood Beach	28 Apr 37	253	75	Unfav.	
Daytona Beach	15 Mar 38	571	75	Unfav.	
Bakers Haulover Inlet	21 May 45	527	79	Unfav.	
Anna Maria & Longboat Keys	12 Feb 47	760	80	Unfav.	
Jupiter Island	13 Feb 47	765	80	Unfav.	
Palm Beach(1)	13 Feb 47	772	80	Fav.	17 May 50
Pinellas County	22 Apr 53	380	83	Fav.	3 Sep 54
Palm Beach County (Lk. Worth Inlet to S. Lake Worth I.)	12 Jul 57	342	85	Fav.	3 Jul 58
Key West	10 Mar 58	413	85	Fav.	14 Jul 60
Amelia Island	**16 Aug 60**	**200**	**87**	**Unfav.**	
Palm Beach County	**23 Aug 60**	**164**	**87**	**Fav.**	
GEORGIA					
St. Simon Island	18 Mar 40	820	76	Unfav.	
HAWAII					
Waikiki Beach	5 Aug 52	227	83	Fav.	3 Sep 54
Waimea & Hanapepe Bay, Kauai	17 Jan 56	432	84	Fav.	3 Jul 58
ILLINOIS					
State of Illinois	8 Jun 50	28	83	Fav.	3 Sep 54

(1) A cooperative study of experimental steel sheet pile groins was also made, under which methods of improvement were recommended in an interim report dated 19 Sep 1940. Final report on experimental groins was published in 1948 as Technical Memo. No. 10 of the Beach Erosion Board.

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	LOUISIANA				
Grand Isle	28 Jul 36	92	75	Unfav.	
Grand Isle	28 Jun 54	132	84	Unfav.	
Belle Pass to Raccoon Point	**13 Jun 61**			**Unfav.**	
	MAINE				
Old Orchard Beach	20 Sep 35			Unfav.	
Saco	2 Mar 56	32	85	Unfav.	
	MASSACHUSETTS				
South Shore of Cape Cod (Pt. Gammon to Chatham)	26 Aug 41			Unfav.	
Salisbury Beach	26 Aug 41			Unfav.	
Winthrop Beach	12 Sep 47	764	80	Fav.	17 May 50
Lynn-Nahant Beach	20 Jan 50	134	82	Fav.	3 Sep 54
Revere Beach	12 Jan 50	146	82	Fav.	3 Sep 54
Nantasket Beach	12 Jan 50			Unfav.	
Quincy Shore	2 May 50	145	82	Fav.	3 Sep 54
Plum Island	18 Nov 52	243	83	Unfav.	
Chatham	22 Oct 56	167	85	Unfav.	
Pemberton Pt. to Cape Cod Canal	13 Jan 59	**272**	**86**	Fav.	14 Jul 60
Wessagusssett Beach, Weymouth	6 Jul 59	**334**	**86**	Fav.	14 Jul 60
Cape Cod Canal to Provincetown	**5 Feb 60**	**404**	**86**	**Fav.**	14 Jul 60
	MICHIGAN				
Berrien County (St. Joseph)	17 Jun 57	336	85	Fav.	3 Jul 58
	MISSISSIPPI				
Hancock County	3 Apr 42			Unfav.	
Harrison County - Initial	15 Mar 44				
Harrison County - Suppl.	16 Feb 48	682	80	Fav.	30 Jun 48

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	NEW HAMPSHIRE				
Hampton Beach	15 Jul 32			Unfav.	
Hampton Beach	14 Sep 53	325	83	Fav.	3 Sep 54
Atlantic Ocean shore (entire)	**30 Jun 61**			**Fav.**	
	NEW JERSEY				
Manasquan Inlet & Adjacent Beaches	15 May 36	71	75	Unfav.	
Atlantic City	11 Jul 49	538	81	Fav.	3 Sep 54
Ocean City	15 Apr 52	184	83	Fav.	3 Sep 54
Sandy Hook to Barnegat Inlet	24 Mar 54	361	84	Fav.	
Review Report - Sandy Hook to Barnegat Inlet	6 May 57	332	85	Fav.	3 Jul 58
Barnegat Inlet to Delaware Bay Entrance to Cape May Canal	22 Sep 58	208	86	Fav.	14 Jul 60
Delaware Bay, Shore - Cape May Canal to Maurice River	**10 Jun 60**	**196**	**87**	**Unfav.**	
	NEW YORK				
Jacob Riis Park, Long Island	16 Dec 35	397	74	Unfav.	
Orchard Beach, Pelham Bay, Bronx	30 Aug 37	450	75	Unfav.	
Niagara County	27 Jun 42	271	78	Unfav.	
South Shore of Long Island	6 Aug 46			Unfav.	
Selkirk Shores State Park	21 Oct 53	343	83	Fav.	3 Sep 54
Fair Haven Beach State Park	18 Jun 54	134	84	Fav.	3 Jul 58
Hamlin Beach State Park	20 Sep 54	138	84	Fav.	3 Jul 58
Braddock Bay State Park	15 Apr 55			Unfav.	
Fire Island Inlet to Jones Inlet	10 Feb 56	411	84	Fav.	3 Jul 58
Fire Island Inlet to Montauk Pt. (combined coop. BEC & Hurr.)	30 Jun 59	425	86	Fav.	14 Jul 60
	NORTH CAROLINA				
Fort Fisher	10 Nov 31	204	72	Unfav.	
Wrightsville Beach	2 Jan 34	218	73	Unfav.	
Kitty Hawk, Nags Head & Oregon Inlet	1 Mar 35	155	74	Unfav.	
State of North Carolina	22 May 47	763	80	Unfav.	
Carolina Beach & vicinity	**10 Mar 61**			**Fav.**	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL RECOMMENDATION	PROJECTS AUTHORIZED BY CONGRESS
	OHIO				
Erie County - Vic. of Huron	26 Aug 41	220	79	Unfav.	
Michigan Line to Marblehead	30 Oct 44	177	79	Unfav.	
Cities of Cleveland & Lakewood	22 Mar 48	502	81	Fav.	3 Sep 54
Chagrin River to Fairport	22 Nov 49	596	81	Unfav.	
Vermilion to Sheffield Lake Village	24 Jul 50	229	83	Fav.	3 Sep 54
Fairport to Ashtabula	1 Aug 51	351	82	Unfav.	
Ashtabula to Penna.St.Line	1 Aug 51	350	82	Unfav.	
Sandusky to Vermilion	7 Jul 52	32	83	Unfav.	
Sandusky Bay	31 Oct 52	126	83	Unfav.	
Sheffield Lake V. to Rocky R.	31 Oct 52	127	83	Unfav.	
Euclid to Chagrin River	25 Jun 53	324	83	Unfav.	
Michigan Line to Marblehead (Review)	**14 Jun 60**	**63**	**87**	**Fav.**	
Sheffield Lake Community Park	**13 Jun 61**			**Fav.**	
	PENNSYLVANIA				
Presque Isle Peninsula, Erie (Interim)	3 Apr 42				
(Final)	23 Apr 52	231	83	Fav.	3 Sep 54
(Review)	**21 Jan 60**	**397**	**86**	**Fav.**	14 Jul 60
	PUERTO RICO				
Punta Las Marias, San Juan	5 Aug 47	769	80	Unfav.	
	RHODE ISLAND				
South Shore (Towns of Narragansett, South Kingstown, Charlestown & Westerly)	4 Dec 48	490	81	Fav.	3 Sep 54
South Kingstown & Westerly	27 Jan 58	30	86	Fav.	14 Jul 60
	SOUTH CAROLINA				
Folly Beach	31 Jan 35	156	74	Unfav.	
Pawleys Is., Edisto Beach & Hunting Island	24 Jul 51			Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
		TEXAS			
Galveston (Gulf Shore)	10 May 34	400	73	Unfav.	
Galveston Bay, Harris County	31 Jul 34	74	74	Unfav.	
Galveston (Gulf Shore)	5 Feb 53	218	83	Unfav.	
Galveston (Bay Shore)	19 Jun 53	346	83	Unfav.	
Bolivar Peninsula (Gulf Shore & Rollover Fish Pass)	8 Jun 59	286	86	Unfav.	
		VIRGINIA			
Willoughby Spit, Norfolk	20 Nov 37	482	75	Unfav.	
Colonial Beach, Potomac R.	24 Jan 49	333	81	Fav.	17 May 50
Virginia Beach	25 Jun 52	186	83	Fav.	3 Sep 54
Virginia Beach (Review)	**13 Jun 61**			**Fav.**	
		WISCONSIN			
Milwaukee County	21 May 45	526	79	Unfav.	
Racine County	5 Mar 52	88	83	Unfav.	
Kenosha	16 Sep 54	273	84	Unfav.	
Manitowoc County	15 Apr 55	348	84	Fav.	3 Jul 58

CURRENTLY AUTHORIZED COOPERATIVE BEACH EROSION STUDIES

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Department of Water Resources, State of California.

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The current studies cover the Orange County Shore north of Newport Bay Harbor, Pt. Delgada to Pt. Ano Nuevo, and a review for the entire area from Point Conception to the Mexican Boundary.

FLORIDA

VIRGINIA AND BISCAYNE KEYS. Cooperating Agency: City of Miami.

Problem: To determine the best method of preventing further erosion and maintaining such sand as now exists along the City and County-owned frontages on the easterly side of Virginia and Biscayne Keys.

BROWARD COUNTY. Cooperating Agency: Board of County Commissioners, Broward County.

Problem: To determine the best method of restoring eroded reaches of beach, and of maintaining the restored reaches and such other reaches as are now in good condition.

BAKER'S HAULOVER -MIAMI BEACH. Cooperating Agency: Office of the County Manager, Dade County.

Problem: To review the report of the 1945 cooperative study of Baker's Haulover Inlet (H. Doc. 527/79/2) and in light of additional data and new conditions determine what modifications in recommendations are appropriate insofar as beach stabilization and Federal participation are concerned, and to determine best method of restoring and stabilizing the beach between Dade County-Broward County line and Government Cut at Miami Beach.

FORT PIERCE. Cooperating Agency: Fort Pierce Beach Erosion District.

Problem: To determine the best method of restoring and maintaining the eroded section of beach immediately south of the ocean entrance to Fort Pierce Harbor. The problem area extends from the inlet south about 3 miles.

HAWAII

WAIKIKI BEACH. Cooperating Agency: Department of Public Works, State of Hawaii.

Problem: To restudy the problem at Waikiki Beach (previously studied and reported on in H. Doc 227/83/1) and determine the best method of preserving and maintaining the beach and counteracting the eroding effects of waves and littoral drift, effectiveness of the completed portions of the existing project, and what modifications, if any, are desirable.

HALEIWA BEACH. Cooperating Agency: Board of Harbor Commissioners, State of Hawaii.

Problem: To determine the best method of preserving or restoring and maintaining the beach and counteracting the eroding effects of waves and littoral currents.

ILLINOIS

EVANSTON. Cooperating Agency: Office of the City Manager, City of Evanston.

Problem: To determine the best method of restoring and improving the beaches at South Boulevard and Grosse Point (Lighthouse) Park to provide public bathing beaches and to protect the upland property against erosion.

MAINE

HILLS BEACH, BIDDEFORD. Cooperating Agency: City of Biddeford.

Problem: To determine the best method of restoration of protective and recreational beaches and protection of shore property.

MASSACHUSETTS

NEW BEDFORD. Cooperating Agency: City of New Bedford.

Problem: To determine the best method of restoring and stabilizing the public beaches to protect the boulevard and provide public bathing area.

FALMOUTH. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring and stabilizing beaches and stabilizing bluff areas along the shore of the town between Nobska Point and the east town line.

ROCKPORT. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring the beach and protecting the beach and cottage development.

SALISBURY BEACH. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring and protecting the beach and protecting the beach development.

MARTHA'S VINEYARD. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best methods of restoring and stabilizing beaches and bluffs on the island of Martha's Vineyard between East Chop and the entrance to Edgartown Harbor.

NEW JERSEY

STATE OF NEW JERSEY. Cooperating Agency: Department of Conservation and Economic Development.

Problem: To determine the best method of preventing further erosion and stabilizing and restoring the beaches, to recommend remedial measures, and to formulate a comprehensive plan for beach preservation or coastal protection. Current studies cover the shore from South Amboy to Shrewsbury River in Raritan and Sandy Hook Bays.

ATLANTIC CITY. Cooperating Agency: City of Atlantic City.

Problem: To determine the effect of Public Law 826, 84th Congress on the existing authorized project for beach erosion control.

PERTH AMBOY. Cooperating Agency: New Jersey Department of Conservation and Economic Development.

Problem: To determine the best method of restoring adequate recreational and protective beaches and providing continued stability to the shores within the area Second Street to Fayette Street.

NEW YORK

ATLANTIC COAST OF LONG ISLAND BETWEEN JONES INLET AND NORTON POINT, AND STATEN ISLAND. Cooperating Agency: Long Island State Park Commission, and New York State Department of Public Works.

Problem: To determine the best method of restoring adequate recreational and protective beaches and providing continued stability to the shores of Nassau County between Jones Inlet and East Rockaway Inlet, the shores of New York City between East Rockaway Inlet and Norton Point, and the shores of Staten Island between Fort Wadsworth and Arthur Kill.

FIRE ISLAND INLET TO JONES INLET. Cooperating Agency: Long Island State Park Commission.

Problem: To review the existing project with particular regard to a sand bypass plant which would substitute continuous dredging in place of periodic dredging at 5-year intervals as presently authorized and prevent westward drifting sand from accumulating in shoals in Fire Island Inlet and thereby depriving this supply from public beaches to the west during the 5-year dredging intervals.

NORTH CAROLINA

OCRACOKE ISLAND. Cooperating Agency: Department of Water Resources, State of North Carolina.

Problem: To determine the best method of protecting the ocean and Pamlico Sound shores of the island against erosion by waves and currents, and providing protection to State highway and other property.

FORT MACON - ATLANTIC BEACH. Cooperating Agency: Department of Water Resources, State of North Carolina.

Problem: To develop permanent solutions to halt erosion and protect resort improvements at Atlantic Beach and protect park facilities and historic Fort Macon.

OCRACOKE INLET TO CAPE LOOKOUT. Cooperating Agency: Department of Water Resources, State of North Carolina.

Problem: To determine the most economical method of restoring the barrier beach islands to suitable sections and stabilizing the ocean shore of the islands.

PUERTO RICO

PT. SALINAS TO PT. VACIA TALEGA (SAN JUAN). Cooperating Agency: Department of Public Works, Commonwealth of Puerto Rico.

Problem: To determine most practical and economical method of preventing further erosion of the shore and stabilizing or restoring the beach, especially aimed to protect existing upland properties and future recreational, industrial or residential development areas.

RHODE ISLAND

NEWPORT. Cooperating Agency: Department of Public Works, State of Rhode Island.

Problem: To determine the best method of preventing shore, bluff and cliff erosion and protecting and maintaining Cliff Walk between the west end of Newport Beach and the east end of Bailey Beach.

SOUTH CAROLINA

HUNTING ISLAND. Cooperating Agency: State Highway Department of South Carolina.

Problem: To determine the best method of arresting erosion and stabilizing the beach at Hunting Island Beach.